A Review of Biopesticide-Based Management of *Helicoverpa armigera* in Chickpea and Mung Bean

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Abstract: Chickpea (*Cicer arietinum* L.) and mung bean (*Vigna radiata* L.) are important pulse crops that play a vital role in nutritional security, soil fertility improvement, and the livelihoods of small and marginal farmers. However, their production is significantly affected by the gram pod borer, *Helicoverpa armigera* (Hübner), a highly destructive and polyphagous pest that damages leaves, flowers, and developing pods, leading to serious yield and quality losses. Conventional management of this pest largely depends on synthetic insecticides, which, although effective, have resulted in issues such as resistance development, environmental pollution, residue problems, and adverse effects on non-target organisms. In recent years, biopesticides have emerged as sustainable and eco-friendly alternatives for managing *H. armigera*. Botanical extracts, microbial agents such as *Bacillus thuringiensis* and nucleopolyhedrovirus (NPV), and entomopathogenic fungi have shown promising results in reducing larval populations and minimizing pod damage in pulse crops. The integration of these biopesticides within an Integrated Pest Management (IPM) framework offers a viable approach for sustainable pulse production and safer food systems.

Keywords: Biopesticides, *Helicoverpa Armigera*, Chickpea, Mung Bean, Integrated Pest Management (IPM).

INTRODUCTION

Chickpea (*Cicer arietinum* L.) and mung bean (*Vigna radiata* L.) are important pulse crops cultivated widely for their high protein content and economic value, particularly in developing countries. These crops contribute significantly to nutritional security and sustainable agriculture due to their ability to fix atmospheric nitrogen and improve soil health. However, their productivity is severely affected by insect pests, among which the gram pod borer, *Helicoverpa armigera* (Hübner), is considered one of the most destructive species. The pest attacks crops at flowering and pod formation stages, feeding on leaves, flowers, and developing pods, resulting in substantial yield losses. [1][2]

Helicoverpa armigera is highly adaptable and exhibits rapid population growth and migratory behavior, making its management challenging. Population dynamics studies in chickpea have shown that pest incidence fluctuates with seasonal conditions, often reaching peak levels during reproductive crop stages. Traditionally, farmers rely heavily on chemical insecticides for managing this pest. Although chemical molecules such as chlorantraniliprole are effective, concerns regarding resistance development, environmental contamination, and non-target toxicity have increased in recent years. [3] Additionally, studies evaluating compounds like spinosad have highlighted their physiological effects on *H. armigera*, indicating the need for careful and judicious application strategies. [4]

In response to the limitations of synthetic insecticides, biopesticides have gained importance as eco-friendly alternatives for sustainable pest management. Biopesticides derived from microbial sources, including entomopathogenic bacteria and viruses, are considered safer to natural enemies and the environment. [5] Field evaluations have demonstrated that bio-pesticides such as *Bacillus thuringiensis* and nucleopolyhedrovirus (NPV), either alone or in combination, can effectively reduce larval populations of *H. armigera* in chickpea. Similarly, recent research has confirmed the efficacy of various biopesticides in minimizing pod damage and improving crop yield under field conditions. [6]

Furthermore, comparative studies between chemical insecticides and biopesticides in pulse crops, including green gram, indicate that bio-based treatments can provide satisfactory control while reducing ecological risks. Although much of the genomic research in lepidopteran pests has focused on species such as *Spodoptera frugiperda*, such studies emphasize the complexity of pest adaptation and the importance of integrated and sustainable management approaches. [7] Therefore, understanding the role of biopesticides within an integrated pest management (IPM) framework is essential for long-term suppression of *H. armigera* in chickpea and mung bean cultivation.

This review aims to synthesize recent findings on biopesticide-based management strategies against *Helicoverpa armigera*, highlighting their efficacy, mechanisms, and potential integration into sustainable pulse production systems.

AGRICULTURE IN INDIA AND CROP LOSSES DUE TO INSECT PESTS

Food security, rural employment, and socio-economic stability are all greatly influenced by India's agricultural sector, which has historically been and will continue to be the country's economic backbone. The agricultural sector provides a living for a sizable segment of India's population. The agricultural industry continues to play a significant role in rural families' income generation and national development, even while the industrial sector and the service sector are seeing tremendous expansion. [8] Reducing poverty, ensuring adequate nutrition, and boosting the economy are all tied to how well the agricultural sector is doing.

Pest insects eat on many parts of plants, including their leaves, stems, roots, blossoms, pods, and grains, and they may harm crops at any point in their development. Crop losses are worsened when some pests spread plant diseases. Due to inferior grain quality, shrivelling, discolouration, and contamination, insect pest damage not only decreases output but also affects market value. Although these intangible losses are often overlooked, they may have a significant impact on farmers' bottom lines. [9]

Due to the fact that the weather is always changing, the problem of insect pest damage becomes even more serious. A multitude of factors, including global warming, changes in rainfall patterns, and an increase in extreme weather events, have altered the dynamics of insect pest populations. As a consequence of climate change, some economically relevant insect pests are becoming more prevalent, which speeds up their life cycles and boosts their chances of survival, according to the findings of researchers. [10] Unpredictable and severe outbreaks of insects are becoming increasingly common, which presents a significant challenge for agricultural produce producers.

Historically, chemical pesticides have been the main tool used by farmers to reduce crop losses. Agricultural output was boosted by the advent of synthetic pesticides, which effectively controlled insect pests at first. Insecticide resistance, secondary pest revival, natural enemy annihilation, environmental pollution, and indiscriminate and excessive chemical usage are some of the negative outcomes that have resulted from this practice. [11]

Reducing crop losses caused by insect pests by sustainable approaches is of utmost significance in the context of Indian agriculture, where small and marginal farmers dominate. Reduced input costs, safer food production, and less pollution may all result from using biopesticides. In order to improve agricultural output and guarantee food security in India, it is crucial to identify the extent to which insect pests cause crop losses and to create effective management techniques based on biopesticides.

NUTRITIONAL AND ECONOMIC IMPORTANCE OF CHICKPEA AND MUNG BEAN

Chickpeas, also known as *Cicer arietinum L.*, are one of the most extensively cultivated pulse crops. They are absolutely necessary for supplying nutrition, income, and food security, particularly in countries that are economically disadvantaged. The term "poor man's meat" is occasionally used to refer to pulses since they provide populations with low incomes a source of protein that is both inexpensive and of excellent quality. Due to the fact that it is loaded with nutrients and may be used in a wide variety of ways in the kitchen, chickpea is considered to be one of the most versatile pulse crops. Because of the prevalence of vegetarianism in India, chickpeas are an essential source of both energy and protein in the country's diet. Its constant usage makes compensate for the protein deficiency that is present in diets that are based on cereal. [12] This results in a significant improvement in nutritional health.

The high protein content of chickpeas which typically falls between 18 and 24 percent is largely responsible for their nutritional excellence. Chickpeas are an important part of healthy diets since they provide a lot of protein, more so than most cereal crops. Proteins from chickpeas are rich in critical amino acids like leucine, arginine, and lysine, which are often lacking in grains of cereal. On the other hand, cysteine and methionine, which are amino acids that contain sulfur, are not abundant in chickpea proteins. Chickpeas, when eaten with cereals, enhance the protein quality of the diet and work well as a supplement to cereal proteins, which is especially helpful for vegetarians in South Asian diets.

The health benefits of chickpea are enhanced by its abundance of bioactive components, including antioxidants, flavonoids, and phenolics. By lowering oxidative stress and cellular damage, these chemicals aid in neutralizing free radicals in the body. It has been shown that the antioxidants included in chickpeas may help reduce inflammation and protect against cancer. There is some evidence that eating chickpeas on a regular basis will lower your chance of developing chronic conditions including heart disease, obesity, type 2 diabetes, and certain malignancies. [13] Chickpeas are becoming more and more known as functional foods that provide health advantages beyond just nutrition.

For tiny and marginal landholders in semi-arid locations, chickpeas are a very significant crop from an economic standpoint. Because of its low input requirements compared to other cereal crops, it is mostly grown in rainfed environments. Chickpeas are an economical crop since they need less in the way of inputs and require less watering. Chickpeas are a popular crop among farmers because of their consistent demand and steady market price. A major factor in raising farm revenue and bettering rural people' lives is the economic feasibility of growing chickpeas.

Growing chickpeas is a great way for people in rural regions to find work. Land preparation, planting, weeding, harvesting, and threshing are just a few of the many steps in agricultural production that need labor. Jobs are also created in the post-harvest processing industry, which includes tasks such as grinding dal, making flour, and preparing snacks. Many rural families rely on these activities for income, which are often carried out at the village or small-scale industrial levels. There is a strong correlation between women's participation in post-harvest activities and their increased agency and economic independence. [14]

The nutritional, economic, and ecological importance of chickpeas places them in a special and irreplaceable position in Indian agriculture. Its significance is highlighted by the fact that it promotes sustainable agricultural techniques, increases farmers' income, and guarantees food and nutritional security. Successful control of yield-limiting variables, especially insect pests, is essential for optimizing chickpea crop advantages. Biopesticides and other sustainable pest control strategies may save chickpea crops without compromising human or environmental health. The full potential of chickpea agriculture can only be realized via ongoing study and the use of environmentally friendly methods."

INSECT PESTS OF CHICKPEA

Infestation by various insect pests is one of the main obstacles to reaching potential yield in chickpea *(Cicer arietinum L.)* since it attacks the crop throughout its growing phase. As they eat on the plant's leaves, blossoms, pods, and grains, insect pests cause harm to the crop at every stage, from planting to harvest. How bad an infestation is depending on farmers' pest control strategies, cropping methods, and agro-climatic conditions. A wide range of herbivorous insects are attracted to chickpeas because of their high nutritional content and delicate leaves.

It has been shown that chickpeas are infested by over 60 distinct types of pest insects worldwide. Lepidoptera, Hemiptera, Coleoptera, and Diptera are only a few of the orders to which these pests belong. Though some of them do periodic economic harm, this is far from the norm. Minor harm is caused by the residual bugs that appear sometimes. The lepidopteran pests are particularly dangerous because of their eating habits and ability to reproduce. [15]

The insect pest complex that chickpeas are susceptible to varies according on the region and the time of year. A significant part of the dynamics of pest populations is determined by climatic conditions such as humidity, temperature, and rainfall. Insect pests are able to rapidly multiply when the circumstances are warm and dry during the blooming and pod development phases. In regions that are dependent on rainwater, the presence of stress conditions often makes pests more prevalent, which results in increased agricultural losses. (Lateef and Pimbert, 1990), the persistent raising of chickpeas in certain areas has also led to the accumulation of pest populations over the course of time.

Insect pests attacking chickpea can be broadly categorized into foliage feeders, sap feeders and pod borers. Foliage feeders such as cutworms and caterpillars cause damage by defoliation, reducing the photosynthetic capacity of the plant. Sap feeders weaken the plant by extracting cell sap, leading to stunted growth and poor pod development. Pod borers directly damage the economic produce by feeding on developing seeds, resulting in substantial yield loss. [16]

Infestations of chickpea, especially during their vegetative stage, may occur from the foliage-feeding tobacco caterpillar (Spodoptera litura). Skeletonization and severe defoliation are caused by the gregarious feeding of the larvae on leaves. Even though it's only a little bug, it can do a lot of harm if the circumstances are right. If leaf feeders get to a plant too early, they might stunt its development and weaken its defenses, which lowers its yield potential.

Bugs that feed on chickpea sap are another major pest group that chickpeas might face. Pests like thrips, aphids, and jassids may attack plants while they're young. By sucking plant sap and injecting toxic saliva, aphids curl the leaves, turn them yellow, and limit the plant's growth. They also discourage the growth of sooty mould, which lowers photosynthesis, by their secretion of honeydew. When aphids take over a plant, it may dry it out completely. [17]

Whiteflies (*Bemisia tabaci*) are another sap-sucking pest that occasionally infests chickpea. Though primarily known as a pest of cotton and vegetables, whiteflies can colonize chickpea under certain conditions. They weaken plants through sap extraction and also act as vectors of viral diseases. Their rapid multiplication and resistance to insecticides make them difficult to manage. Whitefly infestation is more prominent during dry weather conditions and in fields with continuous host availability.

When it comes to chickpea pests, pod borers are by far the worst. The most destructive and pervasive of these pests is the gram pod borer, scientifically known as *Helicoverpa armigera*. By burrowing into blooms and pods, the larvae consume growing seeds for food. During its growth, a single larva may harm many pods, leading to significant losses in production. The pest's polyphagy and adaptability make it a constant danger to chickpea farming.

The damage caused by pod borers is particularly severe during flowering and pod formation stages. Infested pods show characteristic round holes with partially eaten grains. Such damage not only reduces yield but also affects grain quality and market value. Pod borer infestation often leads to secondary infections by fungi and bacteria, further deteriorating seed quality. Yield losses caused by pod borers can vary widely depending on pest pressure and management practices. [18]

Another important pest of chickpea is the leaf miner (*Liriomyza cicerina*), which attacks the crop during early growth stages. The larvae feed within leaf tissues, creating serpentine mines that reduce photosynthetic efficiency. Severe infestation can lead to premature leaf drop and poor plant vigour. Leaf miner damage is more common in cooler regions and under irrigated conditions. Although considered a minor pest, it can cause economic damage when population levels are high.

Soil-dwelling insect pests such as termites (*Odontotermes* spp.) and cutworms also pose a threat to chickpea, particularly at seedling stage. Termites cause wilting and eventual plant death by feeding on underground plant tissues, such as roots and stems. During the night, cutworms nibble at seedlings at ground level, causing uneven crop stand. These pests are more prevalent in dry and sandy soils and can cause significant stand loss if not managed timely. [19]

The incidence and severity of insect pests in chickpea are strongly influenced by cropping systems and agronomic practices. Continuous monocropping, late sowing and excessive nitrogen fertilization often favour pest buildup. Lack of crop rotation and improper residue management further exacerbate pest problems. Understanding the pest ecology and adopting appropriate cultural practices can help minimize pest incidence and reduce reliance on chemical control measures.

The management of insect pests in chickpea is challenging due to overlapping pest generations and prolonged crop duration. Many pests exhibit high reproductive rates and rapid population buildup. Moreover, the presence of multiple host crops in the surrounding landscape ensures year-round survival of pests. These factors complicate pest management and necessitate integrated approaches that combine cultural, biological and chemical methods.

BIOLOGY, DISTRIBUTION AND DAMAGE POTENTIAL OF *HELICOVERPA ARMIGERA*

The gram pod borer, also known as *Helicoverpa armigera* (Hubner) in the scientific community, is one of the insect pests that causes the greatest damage to pulse crops in India, particularly chickpea and mung bean. A member of the order Lepidoptera, the Noctuidae family is the name of this particular insect family. A number of factors contribute to the widespread recognition of this insect, including its desire to rapidly reproduce, its ability to move from one location to another, and its resistance to a variety of pesticides. It is because of these characteristics that *H. armigera* has become a big concern for the production of pulses in a number of locations throughout the country, and Madhya Pradesh, which is located in the center of India, is not an exception. At the larval stage, it feeds directly on pods and flowers, which results in a considerable reduction in both production and quality. This causes severe damage caused by the larval stage. [20]

Range of Hosts and Distribution: *Helicoverpa armigera* has an exceptionally wide geographical distribution and is considered a cosmopolitan pest species. It is widely distributed in Asia, Africa, Europe, Australia and parts of South America. In Asia, the pest is particularly prominent in India, Pakistan, Bangladesh and China, where it attacks a variety of economically important crops. In India, *H. armigera* occurs in almost all agro-climatic regions, ranging from arid and semi-arid zones to humid and sub-humid regions, indicating its remarkable adaptability to diverse environmental conditions.

Importance as a Polyphagous Pest: It is an economically significant pest due to the fact that *Helicoverpa armigera* may consume a wide variety of plant species during the course of the year. The pest is able to maintain a large population size throughout the year because it is able to adjust its feeding habits throughout the year. This enables it to have access to readily accessible food and breeding grounds. The presence of this characteristic renders *H. armigera* a polyphagous pest that poses a significant threat to agricultural ecosystems all over the world.

BIOPESTICIDES IN SUSTAINABLE MANAGEMENT OF *HELICOVERPA ARMIGERA*

Biopesticides are an effective method of pest control that utilizes substances sourced from nature, including plants, microbes, animals, and minerals. To manage pests in a non-toxic or less harmful way, biopesticides rely on naturally occurring chemicals rather than manmade chemical pesticides. Some of their possible effects include preventing food intake, stunting development, warding against pests, or even killing via infection. In general, biopesticides are safe for both the environment and non-target species due to their biodegradability and natural origin.

There are three main types of biopesticides: those that target plants, those that target microbes, and those that target chemicals. Plant extracts with insecticidal or repellant characteristics are the basis of botanical biopesticides. Some examples of such extracts include neem, pyrethrum, and karanj. Bacteria, viruses, fungus, and protozoa are all examples of microbial biopesticides, which infect insects and destroy them. Pheromones and insect growth regulators are examples of naturally occurring chemicals that make up biochemical biopesticides; these substances hinder the behavior or development of pests.

The concept of using biopesticides is closely linked with sustainable agriculture and IPM. Biopesticides are considered compatible with IPM programmes because they are selective in action and conserve beneficial organisms. Their use helps maintain ecological balance while keeping pest populations below economic threshold levels. In recent years, increasing awareness about environmental safety and food quality has accelerated interest in biopesticides as alternatives to chemical pesticides. [21]

Biopesticides act through diverse mechanisms, making them effective tools against insect pests like *Helicoverpa armigera*. Microbial biopesticides such as *Bacillus thuringiensis* and nuclear polyhedrosis virus infect larvae and disrupt their physiological processes, ultimately causing death. Botanical biopesticides mainly act as antifeedants, oviposition deterrents or growth inhibitors, thereby reducing pest damage rather than causing immediate mortality. [22]

In the context of pulse crops such as chickpea and mung bean, biopesticides are particularly important because these crops are consumed directly and are highly sensitive to pesticide residues. The use of biopesticides ensures safer food production while reducing dependence on hazardous chemicals. With increasing restrictions on chemical pesticide use and growing demand for residue-free produce, biopesticides have emerged as an essential component of modern pest management strategies.

Botanical Biopesticides: Botanical biopesticides are plant-derived products that possess insecticidal, repellent or growth-regulating properties and are widely used in sustainable pest management. Among various botanical sources, neem (Azadirachta indica) occupies a unique and prominent position due to its broad-spectrum activity against insect pests and its eco-friendly nature. Neem-based products have been used traditionally in Indian agriculture for centuries and are now recognized globally as effective botanical biopesticides. Their importance has increased in recent years due to growing concerns over environmental pollution and pesticide residues associated with chemical insecticides. Neem contains a wide range of biologically active compounds, collectively known as limonoids, of which azadirachtin is the most potent and well-studied. Other important compounds include salannin, nimbin and meliantriol, which contribute to the insecticidal properties of neem. These compounds do not act as quick poisons but interfere with normal physiological and behavioural processes of insects. As a result, neem-based products are considered safer alternatives to synthetic insecticides, as they reduce pest damage without causing severe ecological disruption.

Microbial Biopesticides: Pest control chemicals generated from microorganisms found in nature, including bacteria, viruses, and fungus, are known as microbial biopesticides. Due to their specialized activity against target species and little influence on non-target organisms, these biopesticides find extensive usage in sustainable agriculture. Because they infect and decrease larval populations without disrupting ecological balance, microbial biopesticides are vital in *Helicoverpa armigera* control. When it comes to controlling lepidopteran pests in pulse crops, the most researched and commercially used microbial agents are Bt and NPV.

Fungal Biopesticides: The use of fungal biopesticides, which are essential microbial agents for the biological control of insect pests, is a significant component of sustainable pest management systems. Fungi are frequent bug illnesses that are transmitted via physical contact rather than through the consumption of food. Fungal biopesticides are effective against insect pests at every stage of their life cycle, from larvae to adults, as a result of the distinctive mechanism of action that they use. Entomopathogenic fungi, including Metarhizium anisopliae, Beauveria bassiana, and Nomuraea rileyi, show tremendous promise for lowering

Helicoverpa armigera populations without upsetting ecological balance when used for management purposes.

LIMITATIONS OF CONVENTIONAL CHEMICAL CONTROL

The management of *Helicoverpa armigera* in chickpea and mung bean has traditionally relied on synthetic chemical insecticides due to their rapid action and immediate reduction of pest populations. However, continuous and indiscriminate use of these chemicals has led to several serious limitations that threaten the sustainability of pulse production systems. Major concerns associated with conventional chemical control include resistance development, environmental contamination, and pesticide residue problems. [23]

One of the most critical challenges in chemical pest management is the development of insecticide resistance. *Helicoverpa armigera* is known for its high reproductive potential, genetic variability, and adaptability, which enable it to rapidly develop resistance to commonly used insecticides. Repeated application of the same or similar chemical molecules exerts selection pressure on pest populations, allowing resistant individuals to survive and multiply. Over time, this reduces the effectiveness of insecticides, leading to increased application frequency and higher doses, further aggravating resistance issues. The emergence of resistance not only increases production costs for farmers but also limits the available chemical options for effective pest control. [24]

Excessive use of chemical insecticides poses significant risks to the environment. Many synthetic pesticides are non-selective and may harm beneficial organisms such as pollinators, natural enemies, soil microbes, and aquatic fauna. Disruption of natural enemy populations can result in secondary pest outbreaks and ecological imbalance. Additionally, pesticide runoff and leaching can contaminate soil and water bodies, affecting biodiversity and ecosystem health. Long-term exposure to chemical pesticides has also been associated with adverse effects on human health, particularly for farm workers and consumers. These environmental concerns have intensified the need for eco-friendly and sustainable pest management alternatives. [25]

Pulse crops like chickpea and mung bean are directly consumed as food, making pesticide residue a major issue. Improper application, excessive dosage, and failure to observe waiting periods can result in chemical residues persisting in harvested produce. Such residues may pose health risks to consumers and can lead to rejection of produce in domestic and international markets due to strict maximum residue limits (MRLs). Residue accumulation also affects export potential and reduces consumer confidence in food safety. Therefore, minimizing pesticide residues has become a priority in modern agriculture, encouraging the adoption of safer alternatives such as biopesticides.

CONCLUSION

The gram pod borer, *Helicoverpa armigera*, remains a major constraint in chickpea and mung bean production due to its wide host range, high reproductive capacity, and destructive feeding behavior. Overreliance on chemical insecticides has created ecological and resistance-related challenges, emphasizing the need for safer and sustainable pest management strategies. Biopesticides, including botanical, microbial, and fungal agents, provide effective and environmentally compatible alternatives for controlling this pest. Their selective action, biodegradability, and compatibility with natural enemies make them suitable components of Integrated Pest Management programs. Although challenges such as variable field performance and formulation stability exist, continued research, farmer awareness, and policy support can enhance their adoption. Therefore, biopesticide-based management represents a sustainable pathway for long-term suppression of *H. armigera* while ensuring environmental safety, reduced chemical dependence, and improved productivity in pulse cultivation.

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